

converted to sulfate, it could be perhaps as high as 0.02 g/bhp-hr.¹⁷⁵ This level of PM emissions would comply with our proposed NTE provisions once consideration is given to the 1.5 times multiplier on the emission standard for NTE test conditions.¹⁷⁶ Since this estimate is made at a worst case condition (assuming 100% conversion of sulfur to sulfate), we feel confident that the PM NTE provisions of this proposal can be met.

Under contract from the California Air Resources Board, two nonroad diesel engines were recently tested for PM emissions performance with the application of a CDPF over a number of transient and steady-state test cycles.¹⁷⁷ The first engine is a 1999 Caterpillar 3408 (480 hp, 18 liter displacement) nonroad diesel engine certified to the Tier 1 standards. The engine was tested with and without a CDPF on 12 ppm sulfur diesel fuel. The transient emission results for this engine are

summarized in Table III.E-1 below. The steady-state emission results are summarized in Table III.1-2. The test results confirm the excellent PM control performance realized by a CDPF with low sulfur diesel fuel across a wide range of nonroad operating cycles in spite of the relatively high engine-out PM emissions from this Tier 1 engine. We would expect engine-out PM emissions to be lower for production Tier 3 compliant diesel engines that will form the technology baseline for Tier 4 engines meeting the proposed standard. The engine demonstrated PM emissions of 0.009 g/bhp-hr on the proposed Nonroad Transient Cycle (NRTC) from an engine-out level of 0.256 g/bhp-hr, a reduction of 0.247 g/bhp-hr. The engine also demonstrated excellent PM performance on the existing steady-state ISO C1 cycle with PM emissions of 0.010 g/bhp-hr from an engine-out level of 0.127, a reduction of 0.107 g/bhp-hr. Thus this engine would be compliant

with the proposed PM emission standard for ≥ 75 hp variable speed nonroad engines.

When tested on the proposed optional constant speed variable load cycle (CSVL) (a test to which this engine would not be subject to under this proposal) the engine-out PM emission levels were 0.407 g/bhp-hr and were reduced to 0.016 g/bhp-hr (a reduction of 0.391 g/bhp-hr) with the addition of the PM filter. As tested this engine would not be compliant with the proposed optional CSVL standard, but this is not surprising given that this Tier 1 engine was designed for variable speed engine operation and not for single speed operation. We have great confidence given the substantial PM reduction realized in this testing over the proposed CSVL cycle with a CDPF that a properly designed nonroad diesel engine will be able to meet the standard of 0.01 g/bhp-hr.

TABLE III.E-1 -- TRANSIENT PM EMISSIONS FOR A TIER 1 NR DIESEL ENGINE WITH A CDPF

1999 (Tier 1) Caterpillar 3408 (480hp, 18l)

Test Cycle	PM [g/bhp-hr]		Reduction %
	Engine Out	w/ CDPF	
Proposed Nonroad Transient Cycle (NRTC)	0.256	0.009	96%
Proposed Constant Speed Variable Load Cycle (CSVL)	0.407	0.016	96%
On-Highway U.S. FTP Transient Cycle (FTP)	0.239	0.019	92%
Agricultural Tractor Cycle (AGT)	0.181	0.009	95%
Backhoe Loader Cycle (BHL)	0.372	0.022	94%
Crawler Tractor Dozer Cycle (CRT)	0.160	0.014	91%
Composite Excavator Duty Cycle (CEX)	0.079	0.009	88%
Skid Steer Loader Typical No. 1 (SST)	0.307	0.016	95%
Skid Steer Loader Typical No. 2 (SS2)	0.242	0.013	95%
Skid Steer Loader Highly Transient Speed (SSS)	0.242	0.008	97%
Skid Steer Loader Highly Transient Torque (SSQ)	0.351	0.004	99%
Arc Welder Typical No.1 (AWT)	0.510	0.018	96%
Arc Welder Typical No.2 (AW2)	0.589	0.031	95%
Arc Welder Highly Transient Speed (AWS)	0.424	0.019	96%
Rubber-Tired Loader Typical No.1 (RTL)	0.233	0.010	96%
Rubber-Tired Loader Typical No.2 (RT2)	0.236	0.011	96%
Rubber-Tired Loader Highly Transient Speed (RTS)	0.255	0.008	97%
Rubber-Tired Loader Highly Transient Torque (RTQ)	0.294	0.009	97%

Table III.E-1 also shows results over a large number of additional test cycles developed from real world in-use test data to represent typical operating cycles for different nonroad equipment applications (see chapter 4.2 of the draft

RIA for information on these test cycles). These test cycles are not used for regulatory purposes, although the information from these cycles was used in developing the proposed NRTC. The results show that the CDPF technology

is highly effective to control in-use PM emissions over any number of disparate operating conditions. Remembering that the base Tier 1 engine was not designed to meet a transient PM standard, the CDPF emissions demonstrated here

¹⁷⁵ An estimate of the maximum sulfate PM emissions rate can be made by assuming a fuel consumption rate (e.g., 0.5 lbm/bhp-hr), the fuel sulfur level (e.g., 15 ppm) and the sulfur to sulfate conversion (e.g., 100% maximum) resulting in a calculated sulfate PM emissions rate of 0.02 g/bhp-

hr. This represents a worst case analysis (100% sulfur conversion with 15 ppm sulfur fuel). In-use emissions would be significantly lower.

¹⁷⁶ The PM standard is expressed to two significant digits 0.01 g/bhp-hr, so when the 1.5 NTE multiplier is applied, the NTE limit becomes

0.015 which is rounded to two significant figures as 0.02 g/bhp-hr.

¹⁷⁷ Application of Diesel Particulate Filters to Three Nonroad Engines—Interim Report, January 2003. Copy available in EPA Air Docket A-2001-28.